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SPECIFICATIONMETHOD FOR THE STATISTICAL MULTIPLEXING OF ATM  
CONNECTIONS

- Inventor A The invention is directed to a method according to the preamble of  
5 A patent claim 1.
- A A plurality of connection types are defined given connections via  
A which information are transmitted according to the asynchronous transfer  
A mode (ATM). Thus, on the one hand, connections having strict demands  
made of the cell delay times are distinguished from connections that do not  
make strict demands of the cell delay times.  
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- Particularly included among the former are connections with which  
A information are transmitted with a constant bit rate (CBR) as well as  
A connections via which real time information are transmitted with variable bit  
rate (rt-VBR).
- 15 The latter include non-real-time VBR connections (nrt-VBR) or  
A connections via which information are transmitted with a variable bit rate  
(available bit rate, ABR) or unspecified bit rate connections (UBR).  
A The information of all five connection types are conducted in ATM  
A cells in common via virtual paths or, respectively, virtual lines having a  
20 A predetermined bit rate (bandwidth). In the course of the setup of new  
connections that have strict demands made of the cell delay times, it is  
A required to calculate the bandwidth that is required for the totality of all  
connections conducted over a connecting section/connecting line or a virtual  
path. For calculating an effective bandwidth, it is necessary to determine the  
rate with which the large cell memory offered for this connection type as well  
as the other connection types (nrt-VBR, ABR, UBR) is allowed to be  
emptied.  
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Upon setup of an ATM connection, the transmitting means must generally inform a higher-ranking control means (all acceptance control) of previously defined parameters. This is required in order to assure the quality  
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of the connection for all subscribers (quality of service). When, for example, too many cells are transmitted and, thus, the transmission capacity is exceeded, too many cells must be discarded. This, however, must be avoided under all circumstances since this involves a loss of information.

- A To this end, for example, the demand for a cell loss ~~property~~<sup>probability</sup> of  $10^{-10}$  of a connection exists on the part of standardization authorities. For this reason, a calculation is already carried out at the call setup ~~performed~~<sup>to determine</sup> as to whether this new connection can be accepted in addition to the connections already existing. When the transmission capacity has already been exhausted, the requested connection is rejected.

A number of transmission parameters are defined for the description of these procedures. These include, for example, the peak cell rate (PCR)

- A defined on a connection. This is thereby a matter of an upper limit for the ~~number~~<sup>rate</sup> of ATM cells that can be transmitted per second of this connection.

Further, the control means is informed of a sustainable cell rate (SCR) by the transmitting means given a connection with variable bit rate. This is the upper limit for an average cell rate with which the cells are transmitted

- A during the existence of the connection. As further parameters, the ~~maximum~~<sup>maximum</sup> possible transmission capacity of the connecting line (link cell rate, C) as

- A well as the ~~maximally~~<sup>maximum</sup> possible load on the connecting line ( $p_0$ ) are known to the control means. The former is a matter of a ~~quasi-material~~<sup>quasi-material</sup> constant of the connecting line, whereas the latter defines a quantity with which the maximally allowable aggregate cell rate on the connecting line is recited.

- A This is usually 95% of the ~~maximally~~<sup>maximum</sup> possible transmission capacity of the connecting line. Based on the measure of these parameters, a decision is then made as to whether new connection requests can be accepted or not.

- A To this end, an algorithm sequences in the higher-ranking control means with which the parameters received from the transmitting equipment are checked. Further, these are compared to parameters that have already been calculated and relate to the momentary load on the connecting line. A decision is then made on the basis of these comparisons as to whether the new connection request is accepted and this connection can still be

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permitted. Among other things, the peak cell rate that has already been addressed or the sustainable cell rate are employed as critical parameters.

A number of methods have developed in the prior art for handling

- A these procedures. Let the sigma rule algorithm be recited here as a simple method. This algorithm is disclosed in detail in German Patent Application 5 DP 196 49 646.7. A <sup>n</sup><sup>th</sup> connection is thereby only allowed when the following is valid for the (n - 1) connections already existing plus the n<sup>th</sup> connection:

$$(a) \quad \sum_{i=1}^n PCR_i \leq p_0 \cdot C$$

- 10 A The connection is likewise allowed when, taking additional properties A of the n connections into consideration, as explained later, the following condition (b) is met.

$$(b) \quad \sum_{VC_i \in \text{class } S} SCR_i + g(c, \text{ class } S) \cdot \left( \sum_{VC_i \in \text{class } S} SCR_i \cdot (PCR_i - SCR_i) \right)^{1/2} \leq p_0 \cdot C - \sum_{VC_i \in \text{class } P} PCR_i$$

whereby  $c = p_0 \cdot C - \sum PCR_i$  is the free capacity for class S.

It can be derived from condition (b) that the pending connections are divided into two classes here. At the beginning of the connection setup,

- 15 A thus, the sigma rule algorithm must make a decision as to which of two classes, namely a class S as well as a class P, the potentially newly added A ATM connection is to be assigned to.

- All virtual connections are assigned to class S for which a statistical multiplexing according to the sigma rule algorithm would yield a noticeable gain compared to the peak cell rate reservation algorithm. The following A condition must be met as criterion for this type of connection for the peak cell rate and the sustainable cell rate of all connections to be statistically A multiplexed:

$$PCR/C < 0.03 \text{ and } (0.1 \leq SCR/PCR \leq 0.5)$$

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- A All other virtual connections are assigned to the class P. These particularly include the connections with constant bit rate. Further, all connections are assigned here for which the parameters SCR as well as PCR lie ~~either very close to or very far from one another~~.
  - A PCR lie ~~very close to one another or very far from one another or that already exhibit a high peak cell rate PCR compared to the overall capacity of the connecting line. A peak cell rate that is greater than 3% of the maximum~~.
  - A ~~maximally possible transmission capacity of the connecting line is valid as a criterion for this.~~

Further, a factor q can be derived from the condition (b). This factor is dependent both on the class S as well as on the free capacity c of the class S. For a defined class S, the  $q(c)$  values must be calculated with a

- A complicated program. In simplifying fashion ~~from dynamics points of view~~, the dependency of the quantity c is estimated by a hyperbola function  $q(c) = q_1 + q_2/c$ .
- A In this prior art, ~~thus, a n<sup>th</sup> virtual connection VC<sub>n</sub> having a defined peak cell rate PCR<sub>n</sub> as well as a sustainable cell rate SCR<sub>n</sub> is allowed in addition to already existing virtual connections VC<sub>i</sub> having the parameters SCR<sub>i</sub> as well as PCR<sub>i</sub> (1 ≤ i ≤ n-1) on a connecting line when conditions (a) or (b) are met.~~

According to the condition (a), a check is carried out to see whether the sum of the peak cell rates of all n connections on the connecting line is

- A equal to or less ~~than the maximum~~ ~~possible transmission capacity on the~~ *an* connecting line. When this is the case, then ~~n<sup>th</sup>~~ <sup>the</sup> virtual connection can be accepted and the interrogation of condition (b) is superfluous. When this is not the case, then a check is carried in condition (b) to see whether the upper estimate of the average value of the sum of the peak cell rates of all connections of the class S together with a cell rate that is calculated from the
- A burst nature of all connections of the class S is less ~~than~~ or equal to the cell rate that is available currently for class S connections. When this is the case, then the ~~n<sup>th</sup>~~ virtual connection is accepted; otherwise, it is rejected.
- A In this prior art, the first class S is, in turn, subdivided into further subclasses S<sub>1</sub>, S<sub>2</sub> or S<sub>3</sub> in order to achieve an even finer classification. In case

A of the arrival of a new connection request, thus, the sigma rule algorithm must check based on the criterion of determined interrogation criteria to

A see which of the sub-classes this new connection is to be assigned to.

5 The most beneficial sub-class  $S_x$  is then automatically selected. A sub-class  $S_x$  is thereby defined via a lower limit or, respectively, upper limit of the peak cell rate PCR as well as of the relationship of the transmission parameters SCR/PCR.

*as shown in Equation (c),*

A Equation (b) thus experiences a modification by the addressed sub-classes  $S_k, P_k$

$$(c) \quad \sum_{VC_i \in S_k} SCR_i + q(c, S_k) \cdot \sqrt{\sum_{VC_i \in S_k} SCR_i \cdot (PCR_i - SCR_i)} \leq c$$

10 whereby  $c = p_0 \cdot C - \sum_{VC_i \in P_k} PCR_i$  is the free capacity for the class S.

A The q factor thus derives as  $q(c, S_k) = q1_{S_k} + q2_{S_k} / c$ .

This connection acceptance algorithm according to this prior art is

A thus in the position of deciding whether a predetermined bandwidth, for

*(e.g., line)*

15 A example the bandwidth of a virtual path or of a line, is adequate overall for a group of connections. Since such acceptance algorithms supply a

A yes/no decision as a result as to whether a connection is to be accepted

A or not, they are not directly suited for the calculation of the effective bandwidth for a group of connections.

20 The effective bandwidth required for a group of connections according to the used sigma rule acceptance algorithm could fundamentally be determined with arbitrary precision by an iterative approximation method. The problem of this method, however, is

A comprised therein that the acceptance algorithm would have to be

25 A multiply run <sup>for each</sup> per connection setup and, thus, would require an extremely great amount of processor capacity.

European Patent Application EP 0 673 138 A2 discloses a method of how a plurality of connections can be conducted over a common

connecting section. Upon arrival of a connection request, a check is thereby carried out to see if adequate bandwidth is still available for accepting this connection. When this is the case, the connection is accepted; otherwise, it is rejected. The calculation of an effective bandwidth, however, is not addressed here.

International Application WO 97/01895 likewise discloses a method of how pending connections are conducted via common connecting sections.

A The goal of such an algorithm, however, is only to accept or, respectively, reject the connection based on the criterion of the remaining bandwidth.

I~> ~~The invention is based on the object of disclosing a way of how an acceptance algorithm is to be fashioned such that a bandwidth representative for all connections can be calculated in an efficient way.~~

I<sup>a</sup> Proceeding on the basis of the features recited in the preamble of patent claim 1, the invention is achieved by the features of the characterizing-part:

- 5 A What is particularly advantageous <sup>in</sup> for the invention is that the sigma rule algorithm is employed as <sup>an</sup> acceptance algorithm. The bandwidth, A proceeding from an initial value, is determined step-by-step with the setup/release of connections. The sigma rule algorithm is started at every step and, in addition to supplying a yes/no decision, supplies an estimate of A the bandwidth based on the prescription of acceptance <sup>criteria and</sup> ~~criteria~~, a conservative traffic parameter value of a class-specific bandwidth is added 10 A or, ~~respectively~~, subtracted. The conservative traffic parameter value is thereby constructed differently in the case of the connection setup than in the case of the connection release. When the sigma rule algorithm determines that the conservative estimate with respect to the bandwidth 15 would be adequate, then a more aggressive traffic parameter value is added A to or, ~~respectively~~, subtracted from the class-specific bandwidth. Here, too, the more aggressive traffic parameter value is fashioned differently in the case of the connection setup than in the case of the connection release.

In > ~~Advantageous developments of the invention are recited in the subclaims.~~

The invention is explained in greater detail below with reference to an exemplary embodiment.

**Shown are:**

- Fig. 1 a flow chart according to the inventive method;  
Fig. 2 a flow chart according to the inventive method.

Fig. 1 shows a flow chart of the inventive method. The initially described sigma rule algorithm SR of the prior art is employed as acceptance algorithm. In accord therewith, additional status variables are introduced in addition to the status variable carried in the sigma rule algorithm SR. What are thereby involved are a matter of the status variables  $c_k^S$ ,  $c_k^P$  and  $c_k^{eff}$ .

- A The status <sup>variable</sup>  $c^S_k$  is a matter of the effective bandwidth of the virtual connections that are to be assigned to one of the classes  $S_k$
- A according to the sigma rule algorithm SR. The status <sup>variable</sup>  $c^P_k$  indicates the sum of the peak cell rates PCR of all virtual connections in the class  $P_k$ ,
- 5 A whereas the status <sup>variable</sup>  $c^{eff}_k$  is defined as effective bandwidth of all <sup>The relations between</sup> connections with reference to the classes k. What thus follows is:

$$(1) \quad c^{eff}_k = c^S_k + c^P_k$$

- Given  $(n-1)$  existing connections  $VC_i$  with the parameters  $PCR_i$ ,  $SCR_i$ , a calculation is then carried out for a connection setup to see whether 1) the new connection  $VC_n$  can be accepted or not; 2) the effective bandwidth  $c^{eff}_k$  that <sup>are</sup> <sub>are [sie]</sub> to be reserved for the  $(n-1)$  existing connections  $VC_i$  including the newly added connection  $VC_n$ .

In a first step, a check is first carried to see whether the new connection  $VC_n$  to be potentially accepted can be assigned to one of the classes  $S_k$  or  $P_k$ . For example, let it be assumed that this can be assigned to one of the classes  $S_k$ . In this case, a check is carried out to see whether the following condition is met for all virtual connections  $VC_i$ , including the connection to be potentially added:

$$(2) \quad \sum_{VC_i \in S_k} SCR_i + q(c^{S_k} + SCR_n, S_k) \cdot \sqrt{\sum_{VC_i \in S_k} SCR_i \cdot (PCR_i - SCR_i)} \leq c^{S_k} + SCR_n$$

- In the above equation, Equation (c) is taken as the basis and the variable  $c$  employed therein is replaced by the bandwidth  $c^S_k$  reserved for the  $(n-1)$  connections plus the average sustainable cell rate  $SCR_n$  that is to be reserved for the  $n^{\text{th}}$  connection  $VC_n$  to be potentially accepted. As can be seen according to Fig. 1, the method is started with a value  $c^S_k = 0$ .

- A strict application of condition (2) likewise yields a bandwidth that is greater than the sum of the peak cell rate  $PCR_n$  of all connections. Since the sum of all added, effective bandwidths, however, is never allowed to lie above the sum of its peak cell rates  $PCR_n$ , condition (2) is modified in such a way that

$$(3) \min \left[ \sum_{VC \in S_k} SCR_i + q(c^{S_k} + SCR_n, S_k) \cdot \sqrt{\sum_{VC \in S_k} SCR_i \cdot (PCR_i - SCR_i)}, \sum_{VC \in S_k} PCR_i \right]$$

$$c^{S_k} + SCR_n$$

Thus, reliability in the estimate is established

- A is taken. A security in the estimate is thus established.

When the above condition applies, then the effective bandwidth

- 5 A employed up to <sup>that point</sup> plus the sustainable cell rate  $SCR_n$  allowed for the  $n^{\text{th}}$  connection  $VC_n$  is taken as <sup>new</sup> effective bandwidth  $c^{S_k}$ . As a result thereof,
- A the following <sup>conditions applies</sup> derives:

$$(4) c^{S_k} := c^{S_k} + SCR_n$$

When the condition (3) is not met, the effective bandwidth employed up to

- 10 A <sup>that point</sup> plus the peak cell rate  $PCR_n$  allowed for the  $n^{\text{th}}$  connection  $VC_n$  is taken as <sup>new</sup> effective bandwidth  $c^{S_k}$ . Accordingly, the following condition applies:
- A as <sup>new</sup> effective bandwidth  $c^{S_k}$

$$(5) c^{S_k} := c^{S_k} + PCR_n$$

When the new connection  $VC_n$  to be potentially added is to be allocated to one of the classes  $S_k$ , a value for the effective bandwidth  $c^{eff_k}$  has thus been found.

When the new connection  $VC_n$  to be potentially added cannot be assigned to one of the classes  $S_k$ , it is automatically assumed that it is to be allocated to one of the classes  $P_k$ . The following thus derives:

$$(6) C^{P_k} := c^{P_k} + PCR_n$$

20 Upon employment of Equation (1), the effective bandwidth  $c^{eff_k}$  can then be

- A calculated:

$$C^{eff_k} = C^{S_k} + C^{P_k}$$

An effective bandwidth has thus been found for the case of a connection setup.

Subsequently, it then must also be determined whether the new connection  $VC_n$  can be accepted. To this end, the condition

$$C^{eff_k} \leq Po \cdot C$$

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must be met.

It is assumed below according to Fig. 1 that a connection release is to be implemented. It is thereby assumed that a connection  $VC_n$  is released given  $n$  existing connections  $VC_i$  having the parameters  $PCR_i$ ,  $SCR_i$ .

- Given release of the connection, a check is first carried out to see whether this <sup>~~pertaining~~</sup> connection  $VC_n$  was allocated to one of the classes  $S_k$ . In this case, an interrogation criterion is applied to all remaining virtual connections  $VC_i$  (accept the connection  $VC_n$ ) according to condition (7):

$$(7) \quad \sum_{VC_i \in S_k} SCR_i + q(c^{S_k} - PCR_{n,i}, S_k) \sqrt{\sum_{VC_i \in S_k} SCR_i (PCR_i - SCR_i)} \leq c^{S_k} - PCR_n$$

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A strict application of condition (7) now potentially yields a bandwidth for the remaining  $(n-1)$  connections that is greater than the sum of the peak cell rates of the connections. Condition (7) is therefore to be modified in such a way that

$$(8) \quad \min \left[ \sum_{VC_i \in S_k} SCR_i + q(c^{S_k} - PCR_n, S_k), \sqrt{\sum_{VC_i \in S_k} SCR_i (PCR_i - SCR_i)}, \sum_{VC_i \in S_k} PCR_i \right]$$

$$\leq c^{S_k} - PCR_n$$

derives.

- A When the above condition applies, then the effective bandwidth applied up to <sup>this point</sup> minus the peak cell rate  $PCR_n$  allowed for the  $n^{\text{th}}$  connection  $VC_n$  is taken as new, effective bandwidth  $c^{S_k}$ . Deriving therefrom is:

$$(9) \quad c^{S_k} := c^{S_k} - PCR_n$$

- A When condition (8) is not met, then the effective bandwidth employed up to <sup>this point</sup> then minus the sustainable cell rate  $SCR_n$  for the  $n^{\text{th}}$  connection  $VC_n$  is taken  
A as new effective bandwidth  $c^{S_k}$ .

$$(10) \quad c^{S_k} := c^{S_k} - SCR_n$$

A value for the effective bandwidth  $c_k^{\text{eff}}$  has been found for the released connection  $VC_n$  that was allocated to one of the classes  $S_k$ .

When the released connection  $VC_n$  was not allocated to one of the classes  $S_k$ , it is automatically assumed that it was allocated to one of the classes  $P_k$ . The following thus derives:

$$(11) \quad c^{P_k} := c^{P_k} - PCR_n$$

Upon application of Equation (1), the effective bandwidth  $c_k^{\text{eff}}$  can then be calculated:

$$c_k^{\text{eff}} = c^{S_k} + c^{P_k}$$

An effective bandwidth has thus been found for the case of a connection release.

A <sup>embodiment</sup>  
 In one development of the invention, it is provided to replace Equation  
 (10) with <sup>can be replaced with:</sup>

$$(12) \quad c^{s_k} = \min \left[ c^{s_k} - SCR_{s_k}, \sum_{v \in S_k} PCR_v \right]$$

Upon release of connections that were allocated to one of the classes  $S_k$ , the value of the class-specific bandwidth  $c^{s_k}$  is thus upwardly limited by the sum of the peak cell rate of all connections allocated to the classes  $S_k$ . The corresponding conditions are shown in Fig. 2

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